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WŁADYSŁAW CELEBAŃSKI
PIOTR PIECHOTA

Methods for adjusting the braking force of winders with a traction sheave to prevent the risk of wire rope slippage

In Koeppe winders, the emergency braking deceleration values must be higher than the values required by mining regulations and lower than the critical deceleration values due to the risk of hoisting rope slippage. Slippage of suspension ropes can lead to damage to the traction sheave lining and, in extreme conditions, serious damage to the shaft hoist. In order to limit the braking force to a safe value, the air or hydraulic oil pressure in the braking systems of winders is regulated during braking.
This paper presents methods for adjusting pressure in braking systems during braking and their influence on: the risk of slippage of the suspension ropes, the dynamics of the driving system and the dynamics of the skips themselves. Particular attention was paid to the solution in which the braking force varies during the braking process which can cause large changes in the value of the force acting on the winder.

Key words: *rope slippage, Koeppe sheave, braking deceleration, oscillations*

1. INTRODUCTION

In winders with a traction sheave, the braking torque during emergency braking must be such that the brake provides the performance required by law without exceeding the critical deceleration values.

The brake during emergency braking of winders should cause a deceleration of at least 1.5 m/s^2, and in winders with a traction sheave, the deceleration caused by the brake may be less than 1.5 m/s^2, but not less than 1.2 m/s^2 if the deceleration of 1.5 m/s^2 would cause the critical decelerations to be exceeded. The requirements are specified in the Polish Regulation of the Minister of Energy, 2017, §567 [1].

The critical deceleration for a given hoist under specified travel and load conditions is the smallest deceleration beyond which slippage of the rope relative to the traction sheave can occur (loss of frictional engagement).

Slippage of suspension ropes can lead to damage to the traction sheave lining and, in extreme conditions, serious damage to the shaft hoist.

The first part of the article will present the influence of the method of adjusting braking torque during emergency braking on the degree of risk of slippage of the suspension ropes, and in the second part on the dynamics of the drive system and the dynamics of the skips themselves.

2. INFLUENCE OF THE METHOD OF BRAKING TORQUE CONTROL DURING EMERGENCY BRAKING ON THE DEGREE OF SUSPENSION ROPES SLIPPAGE RISK

With respect to the way in which the braking torque is adjusted during emergency braking, the braking systems of winders can be divided into three groups:

1) braking systems capable of applying a braking torque of one constant value for all types of lift travel during emergency braking;
2) braking systems with two different values of braking torque depending on the type of lift travel;
3) constant deceleration braking systems that adjust braking torque during braking so that, regardless of the type of travel, the deceleration during braking has a constant set value.

They have been termed by Tadeusz Zmysłowski [2] as single-program, dual-program and adjusting systems.

The influence of the method of adjusting braking torque during emergency braking on the degree of suspension ropes slippage risk will be presented on the basis of the analysis of actual measurements of the deceleration during emergency braking of two shaft hoists, in which the method of braking torque adjustment was changed as a result of the modernization of the winder.

2.1. Pneumatic winder with a radial brake

The shaft hoist is a single-rope hoist and has two 4-story cages designed for transporting people and/or hoisting and conveying material. The winder is equipped with a radial braking system with cylindrical brake races and a pneumatic axial drive of HOP – VI type.

Until the retrofit of the winder, during emergency braking the brake control system was capable of applying a single braking torque value for all types of hoist travel. After the retrofit, the brake control system is capable of applying two braking torque values depending on the type of travel.

The actual deceleration during emergency braking was measured before and after the retrofitting of the winder.

For a better presentation of the results, measurements are presented for extreme travel cases, i.e., emergency braking when traveling with empty cages and when traveling with maximum excess load. The measurement results are summarized in Tables 1 and 2.

Table 1

Deceleration during emergency braking for a single value of braking torque for all types of winder travel

Direction of travel	Load [kg]	Deceleration [m/s^2]			Quotient b_{rz}/b_{kr}	Quotient b_{rz}/b_{min}
		critical b_{kr}	minimum b_{min}	real b_{rz}		
Cage A↑	0	3.18	1.20	3.05	0.96	2.54
Cage A ↑	Qw = 10000	4.54	1.20	3.56	0.78	2.97
Cage A ↓	Qm = 10000	1.97	1.20	1.33	0.67	1.11

Table 2

Deceleration during emergency braking for two braking torque values for all types of winder travel

Direction of travel	Load [kg]	Deceleration [m/s^2]			Quotient b_{rz}/b_{kr}	Quotient b_{rz}/b_{min}
		critical b_{kr}	minimum $b_{\min}$	real b_{rz}		
Cage A↑	0	3.08	1.20	2.71	0.88	2.26
Cage A ↑	Qw = 10000	4.43	1.20	3.26	0.74	2.72
Cage A ↓	Qm = 10000	1.93	1.20	1.59	0.82	1.33

The tables also show the actual deceleration values during emergency braking referenced to the critical and minimum deceleration values.

The winder brake shall apply a braking torque such that the following conditions are met during emergency braking for all types of travel:

– $b_{rz}/b_{kr} \leq 1$,
– $b_{rz}/b_{min} \geq 1$.

A comparison of these values for the case of a braking system capable of applying single or two braking torque values is shown in the following graphs (Figs. 1 and 2).

On the basis of measurements of deceleration during emergency braking of this shaft hoist, it can be concluded that for winders with a braking system capable of applying only one constant value of braking torque for all types of travel, the greatest difficulty is to meet the requirements of mining regulations simultaneously for empty skip travel and downward travel with excess load.

The braking torque during downward travel with an excess load must be large enough to make the deceleration value during emergency braking greater than 1.2 m/s^2, which makes the deceleration value dangerously close to the critical deceleration value during emergency braking in the case of empty skip travel. This condition is very undesirable and increases the danger of ropes slipping on the traction sheave.

This problem can be solved to a large extent by using a braking system capable of applying two braking torque values depending on the type of travel. In the above case, one braking torque value has been assigned for the downward travel with material and another for the other types of travel.

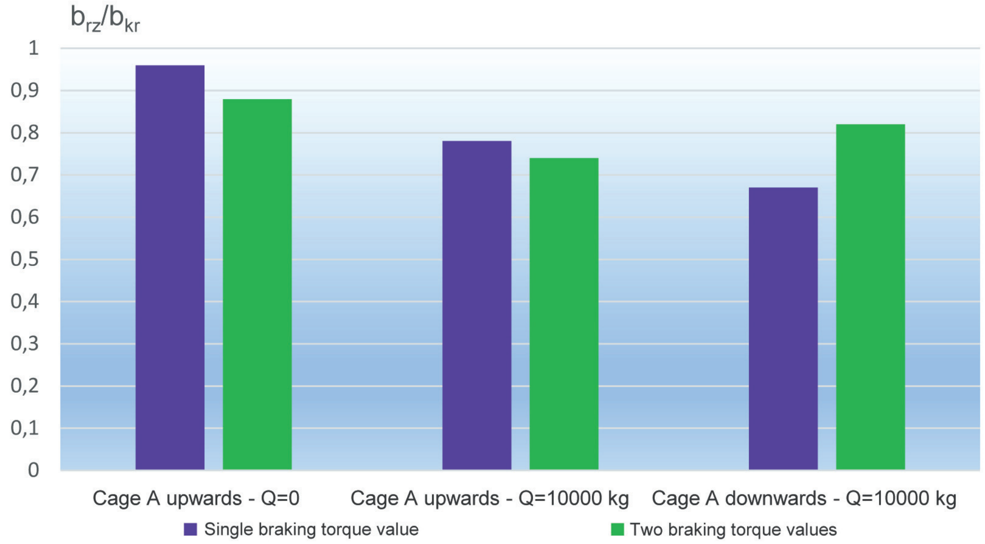

Fig. 1. Comparison of the quotient of actual deceleration to critical deceleration for single and two braking torque values

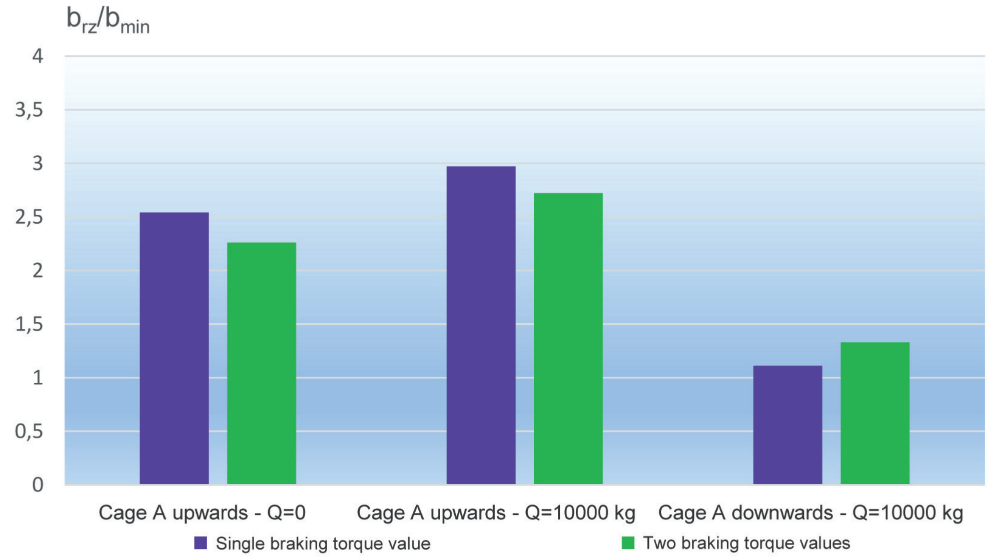

Fig. 2. Comparison of the quotient of actual deceleration to minimum deceleration for single and two braking torque values

This reduced emergency braking deceleration during empty-skip travels and increased deceleration during downward travel with excess load. The risk of slippage is reduced and, at the same time, the effectiveness of the brake is increased when braking during downward travel with excess load.

2.1. Hydraulically retractable disc brake winder

The mine hoist is a four rope, two skip winder equipped with hydraulically retractable disc brakes with a spring drive. Until the retrofit of the winder, during emergency braking the brake control system was capable of applying a single braking torque value for all types of hoist travel. After retrofitting, the brake control system is capable of applying a braking torque with a value that varies in time in such a way that, irrespective of the type of travel, the deceleration during emergency braking has a constant set value. The only exception is downward travel with excess load, where the braking system brakes with a constant preset torque value.

The following tables show the emergency braking test results for both cases.

A comparison of the actual deceleration values during emergency braking relative to the critical and minimum deceleration values for the case of constant and variable braking torque is shown in the graphs (Figs. 3 and 4). From Tables 3 and 4, it can be seen that the risk of slippage is significantly less for adjustable torque braking compared to constant torque braking. The difference between the critical deceleration for controlled torque braking is 0.71 m/s^2 and for constant torque braking is close to zero (0.02 m/s^2).

On the basis of the measurements of the decelerations during emergency braking for this shaft hoist, it can be stated that the use of the braking system capable of obtaining variable braking torque so that the deceleration during braking has a constant set value regardless of the type of travel, considerably reduces the risk of ropes slipping on the traction sheave.

There was a significant decrease in the quotients of the actual deceleration values relative to the critical values for travels with empty skips and upward with extracted material.

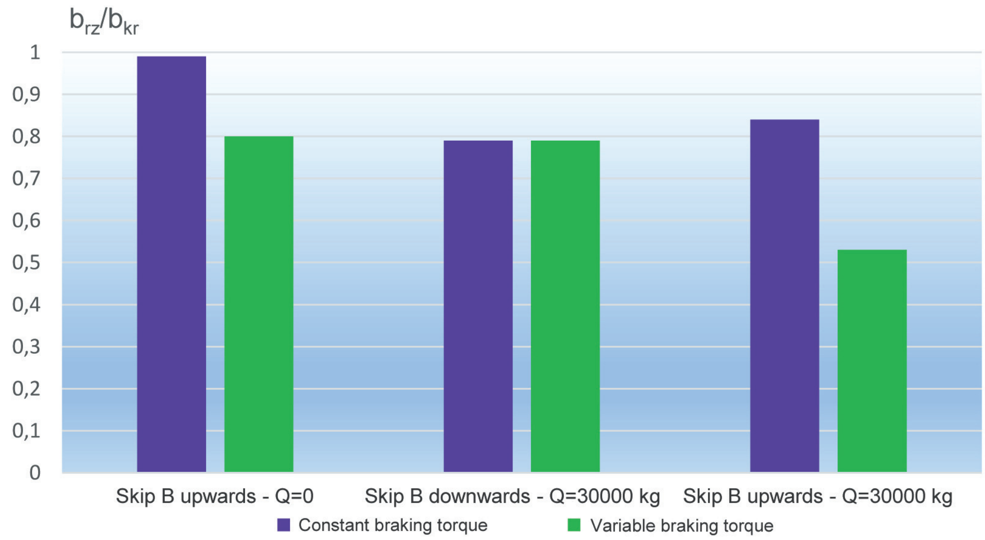

Fig. 3. Comparison of the quotient of actual deceleration to critical deceleration for constant and variable braking torque

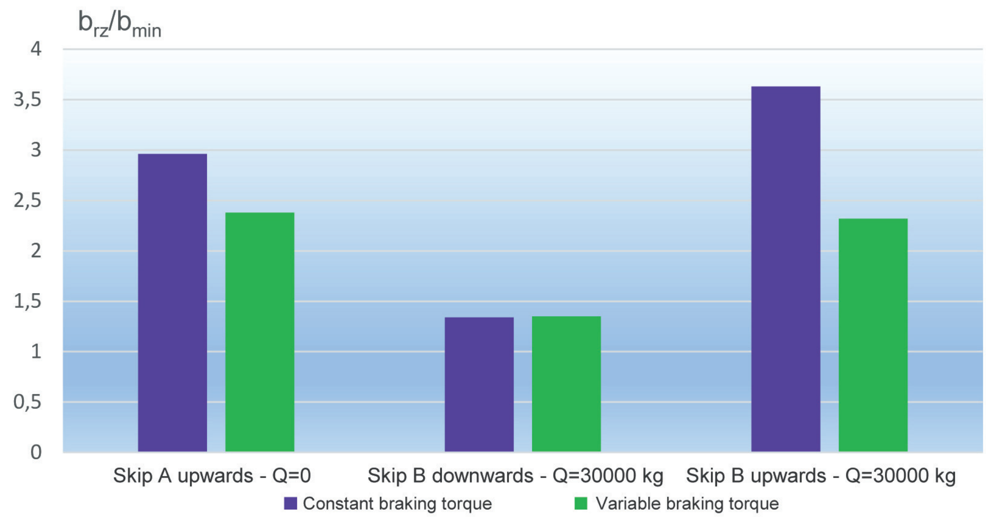

Fig. 4. Comparison of the quotient of actual deceleration to minimum deceleration for constant and variable braking torque

Table 3
Deceleration during emergency braking for the case of one constant braking torque value for all types of winder travel

Direction of travel	Load [kg]	Deceleration [m/s²]			Quotient b_{rz}/b_{kr}	Quotient b_{rz}/b_{min}
		critical b_{kr}	minimum b_{min}	real b_{rz}		
Skip B↑	0	3.57	1.20	3.55	0.99	2.96
Skip B ↓	Qw = 30000	2.04	1.20	1.61	0.79	1.34
Skip B ↑	Qw = 30000	5.20	1.20	4.36	0.84	3.63

Table 4
Deceleration during emergency braking for the case of variable braking torque

Direction of travel	Load [kg]	Deceleration [m/s²]			Quotient b_{rz}/b_{kr}	Quotient b_{rz}/b_{min}
		critical b_{kr}	minimum b_{min}	real b_{rz}		
Skip A↑	0	3.57	1.20	2.86	0.80	2.38
Skip B ↓	Qw = 30000	2.04	1.20	1.62	0.79	1.35
Skip B ↑	Qw = 30000	5.20	1.20	2.78	0.53	2.32

3. EFFECT OF BRAKING TORQUE CONTROL DURING EMERGENCY BRAKING ON THE DYNAMICS OF THE SKIPS

In winder control systems, speed measurement is usually performed by measuring the rotational speed of the traction sheave. In order to investigate the behavior of the skips during emergency braking, it was necessary to measure the velocity of the skip itself. This was accomplished by using an accelerometer that measures the vertical acceleration of the skip and then determining the velocity from it.

Measurements were taken for two skip winders: one with a control system capable of applying two braking torque values depending on the type of travel, and the other with a variable braking torque so that the braking deceleration has a constant value regardless of the type of travel.

3.1. Disc brake winder – variable braking torque

The recordings (Figs. 5 and 6) show the braking process of the skip device recorded at the traction sheave of the winder and at the skip itself. The registration shows the acceleration a [m/s²] rather than the deceleration b [m/s²].

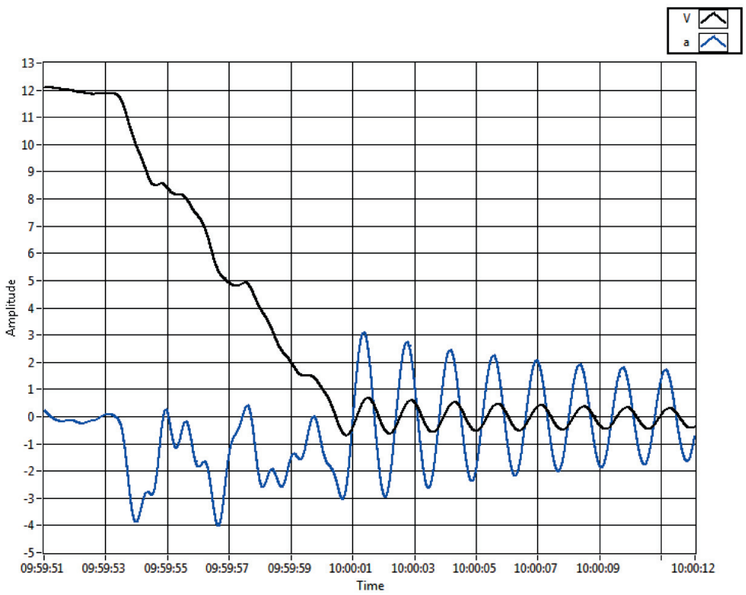

Fig. 5. Skip braking dynamics recorded at the skip: speed V [m/s], acceleration a [m/s²]

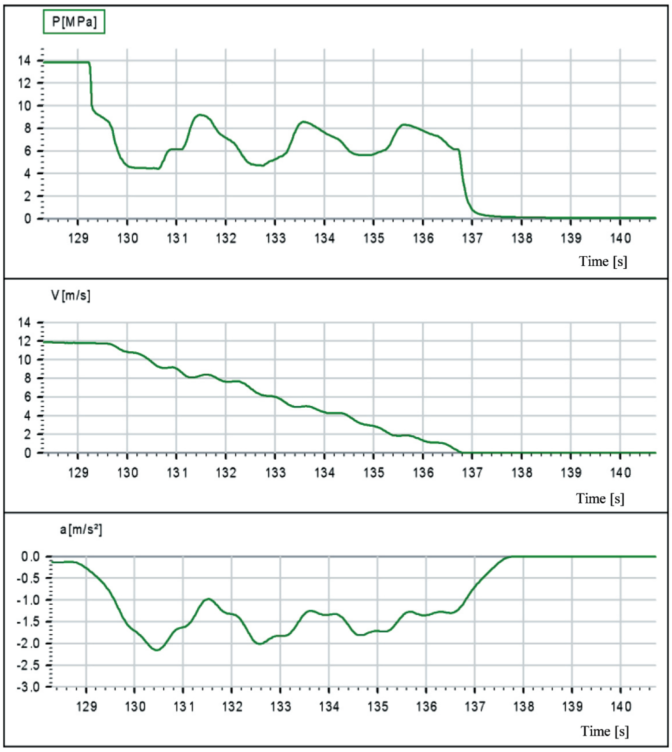

Fig. 6. Dynamics of skip braking recorded at the traction sheave (P – pressure, V – velocity, a – acceleration)

The winder is equipped with hydraulic disc brakes with full pressure control during the braking process. We can observe the fluctuation of the pressure and hence the braking torque in Figure 5. The large amplitude of the braking torque generates vibrations of the entire system: traction sheave – ropes – skips. The instantaneous deceleration may exceed the critical deceleration value creating a slippage risk. The acceleration fluctuation of the skip during braking reaches the value of almost 0.5 g. After stopping the traction sheave, the fading fluctuations of the skip can be observed with a large amplitude of about 6 m/s^2 immediately after the stop.

3.2. Air brake winder – two braking torque values

The following recordings (Figs. 7 and 8) show the braking process of a skip winder equipped with pneumatically driven brakes. In this device, a constant braking torque selected by the control system from two possible ones is maintained during the braking process. The braking process itself is smoother due to the constant braking torque, whereas the very high oscillation of the winder skip can be observedafter stopping.

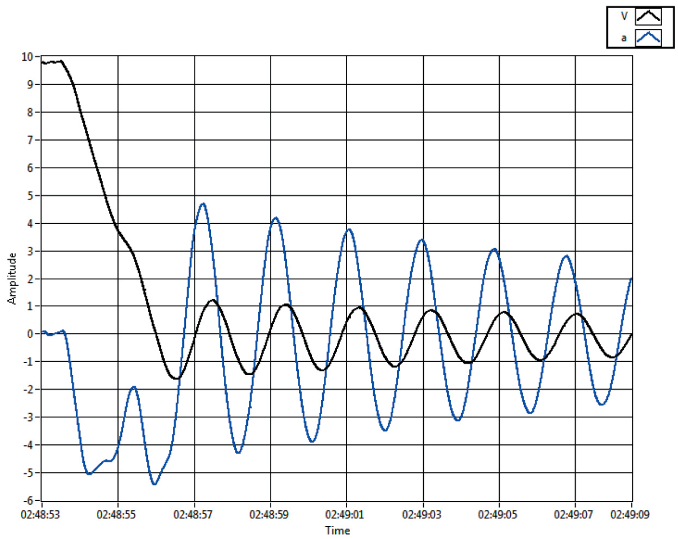

Fig. 7. Dynamics of skip deceleration recorded at the skip: velocity V [m/s], acceleration a [m/s^2]

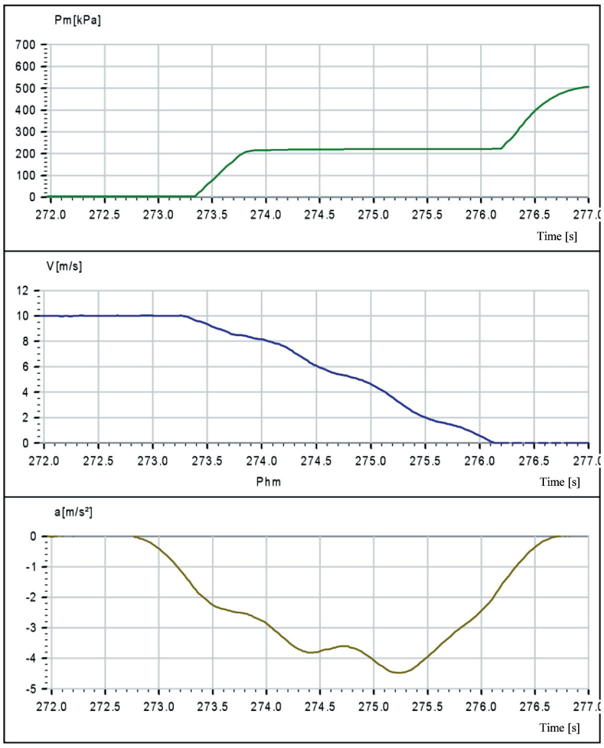

Fig. 8. Dynamics of skip braking recorded at the traction sheave (P – pressure, V – velocity, a – acceleration)

4. CONCLUSIONS

On the one hand, the braking torque control methods used in modern winders ensure adequate brake performance and, on the other hand, prevent the rope from slipping.

The programmable controllers used in the brake control system usually have a large amount of computing power. It could be used to modulate the braking force during emergency braking in such a way as tonot lead tothe oscillation of the drive system, which in turn would extend the life of the mechanical components of the drive system. Modulation of braking force has already been implemented e.g. in the Anico Eagle winder presented by Marian Wójcik [3] but these solutions have not yet been applied on a wide scale.

References

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WŁADYSŁAW CELEBAŃSKI, M., Sc., Eng.
PIOTR PIECHOTA, M., Sc., Eng.
Centrum Badań i Dozoru Górnictwa Podziemnego Sp. z o.o.
ul. Lędzińska 8, 43-143 Lędziny, Poland
p.piechota@cbidgp.pl